SIS18 UPGRADE: THE FAIR COMPLIANT RENOVATION OF THE DATA ACQUISITION SYSTEM FOR PARTICLE DETECTORS

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Abstract

In preparation of FAIR, several well-established beam instrumentation systems of the GSI heavy-ion synchrotron SIS18 and its connected high-energy beam transfer lines (HEBT) have to be modernised. In this contribution, the data acquisition upgrade of particle detectors such as ion chambers and plastic scintillators is described. This covers the replacement of outdated custom-built readout- and control hardware by modern FMC (FPGA mezzanine card) based I/O hardware, new multi-channel high voltage power supplies and a new data acquisition system (DAQ) for the VME based scalers. The latter will replace the old Kylix-based ABLASS software by LASSIE (Large Analog Signal and Scaling Information Environment) to fit into the new FAIR control system concept. LASSIE is based on FESA (Front End Software Architecture). FESA was originally developed by CERN and enhanced by GSI-specific modifications. Furthermore, the new particle detector DAQ will be able to take full advantage of the new FAIR timing system which is based on the White Rabbit protocol.

INTRODUCTION

For the upcoming FAIR project, many parts of the existing GSI facility have to be modernised. The new control system for FAIR is already operational and currently under test by different GSI departments. It is based on the FESA framework [1] which originally was created by CERN and is now being developed in a collaborative effort with GSI. FESA controlled devices are automatically integrated in the control system and can be accessed in a standardised way. If existing hardware has to be replaced or new hardware is installed, a FESA class is programmed to provide future-proof operation. Recently, a renovation project was started to replace outdated high voltage power supplies and to upgrade the readout software called ABLASS [2] of the SIS18 and High Energy Beam Transfer (HEBT) particle detectors.

HIGH VOLTAGE CONTROL FOR PARTICLE DETECTORS

Several particle detector systems need high voltages (HV) to operate. Currently three main types of particle detectors are used by the GSI beam instrumentation (BI) group in the synchrotron and the HEBT: secondary electron monitors (SEM), ionisation chambers (IC) and plastic scintillators (SC). It is possible to mount these three detectors onto a single pneumatic actuator which is called Particle Detector Combination (PDC). Along the existing synchrotron and the HEBT 13 PDCs are installed. Besides the PDCs, also other devices like beam loss monitors or profile grids need HV resulting in over 120 required channels. The different detectors need specific voltages ranging from -1500V to +1500V.

The existing HV system is based on SY127 40-channel crates by the company CAEN [3]. The crates have been in operation for over 20 years and replacement modules are slowly phasing out. Moreover they are controlled via the slow CAENET bus which can delay new settings for HV channels.

Succeeding HV systems from the companies Wiener [4], iseg [5] and CAEN are already installed at GSI and prepared for operation. These systems provide Ethernet enabled controllers and various HV modules with different voltage and current ranges.

Although both systems are controlled over Ethernet, they use different protocols: The crates from Wiener, called MPOD, are accessible via SNMP (Simple Network Management Protocol). The HV modules for MPOD are manufactured by the company iseg and are also fully controllable via SNMP. At GSI, two different MPOD systems are used: The 'MPOD Mini' crate with 4 slots (see Fig. 1) and the standard MPOD crate with 10 slots for HV modules. The most commonly used HV modules at GSI are 16-channel modules providing a positive or negative voltage up to 3000V at a maximum current of 3 mA.

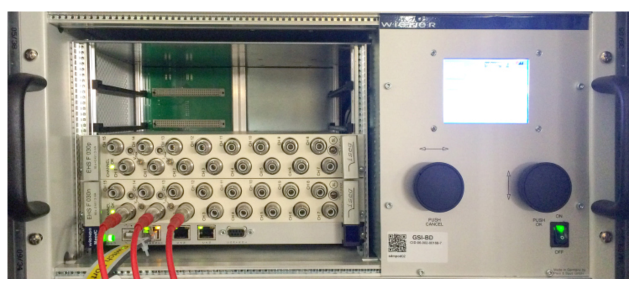

Figure 1: MPOD mini crate with four HV module slots. The lower two slots are populated with iseg modules.

CAEN features a different communication approach: The company provides proprietary libraries to interface with the hardware via Ethernet. The libraries are available for Windows and Linux and can be easily integrated into custom applications like FESA classes. The library offers an efficient monitoring feature for the current line of crates (SY4527 and SY5527). The so-called 'event mode' allows subscriptions to all available crate, board and channel properties. Whenever one of the subscribed values like current, voltage or status registers change, the hardware notifies the application of the change via the library. This way, the devices don't need to

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be polled periodically reducing unnecessary network load significantly.

Due to the different communication methods, two separate FESA classes have been created to control Wiener and CAEN HV systems respectively. The FESA classes were designed with a common interface in mind. In most cases, it is not important for the control system or a human operator which underlying hardware is providing HV to a device. Using the same software interface in FESA, the hardware is completely hidden from the upper control layers. When voltages, current limits or ramping speeds are set, the FESA class for the specific HV system passes the values to the hardware over the hardware-specific protocol. Any settings or status bits that are specific to one particular HV system are mapped to special fields in the FESA classes and can be controlled through an expert's GUI.

DATA ACQUISITION UPGRADE FOR PARTICLE DETECTORS

The readout of the different particle detector types follows a common principle: Electrical pulses are counted in VME scaler modules. Several VME crates are equipped with Struck SIS3820 scaler boards providing 32 channels each.

Previous DAQ System

The ABLASS system (A Beam Loss measurement And Scaling System), in operation since 2004, is collecting the scaler values and presents them in various GUI applications in the main control room. It is a Kylix based application and hard to adapt to new hardware and software conditions like the new control system. Critical system components like custom-built timing receivers will be replaced with White Rabbit [6] timing receivers in the near future. Therefore, also ABLASS is replaced with a new system called LASSIE (Large Analogue Signal and Scaling Information Environment) [7].

Software Upgrade: LASSIE

LASSIE is already in operation and gradually replacing ABLASS. An overview can bee seen in Fig. 2. The signals of the detectors are pulse shaped and fed into VME scaler modules in three VME crates. The readout is done with FESA classes which provide the measurement values to the control system and GUI applications. Two crates are responsible for the readout of ICs, SEMs and SCs detectors. The third crate is used for advanced signal analysis. It provides the possibility to sample dedicated channels with higher sampling rates. Several GUI applications in the main control room allow the timing related correlation of multiple detector channels. Additionally, other data sources like magnet ramps or signals of rf systems (e.g. synchrotron cavities) can be displayed in conjunction with detector data to provide a powerful tool to the machine operators.

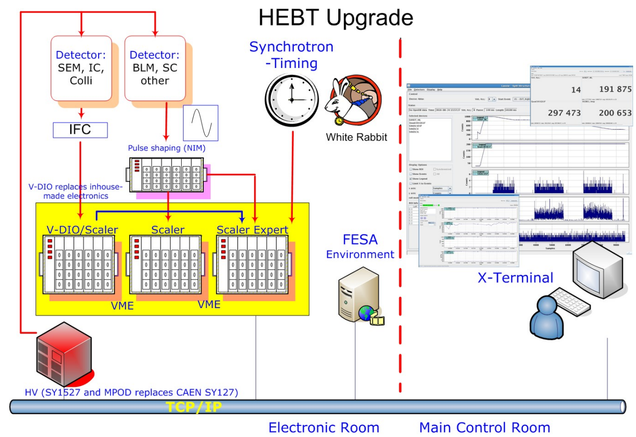

Figure 2: LASSIE overview. Signals from the hardware are fed into scaler modules in three VME crates. FESA classes running on the crates acquire the values and provide the data to the control system or specialised GUI applications.

Hardware Upgrade: V-DIO

SEMs and ICs do not provide a countable signal directly. They provide their measurement value as an electric current which is converted by a specialised hardware called IFC (Current to Frequency Converter) [8] into a countable signal.

The IFC hardware has several discrete control lines for calibration, test signal activation, range setting and polarity setting. Besides the countable measurement signal, it also provides hardware status information via separate lines for overload, device id and gas flow.

The IFCs have been integrated into the old GSI control system using a in-house built hardware setup. The upcoming new control system and the lack of replacement parts for the old hardware made the development of a replacement solution necessary: The VME Digital IO (V-DIO) system was developed by the company MagentaSys [9] based on GSI specifications.

The V-DIO System

The V-DIO system is the new control hardware for the IFCs at GSI and FAIR. To make it more versatile, also a 'general purpose' mode has been implemented, bringing NIM or TTL inputs and outputs for arbitrary applications into the control system. The VDIO system consists of several boards which can be seen in Fig. 3:

- FMC (FPGA Mezzanine Card): Provides ten outputs, two inputs and status LEDs at the front panel.
- SVEC (Simple VME FMC Carrier): Carrier board for up to two FMCs. It was designed by CERN as a White Rabbit Timing receiver and FMC carrier board [10].
- RTM (Rear Transition Module): A 80mm VME RTM board offering four slots for mezzanine boards.
- Mezzanine boards: Mounted on the RTM and connect directly to an IFC. They can be switched to 'general purpose mode' to provide I/O lines for arbitrary use. A close-up can be seen in Fig. 4

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Figure 3: The different boards of the VDIO system. From left to right: small FMC board with front connectors mounted on a 6 HE SVEC VME board, RTM carrier with four rear mezzanine boards, deported IO baseboard with attached mezzanine, single rear mezzanine board.

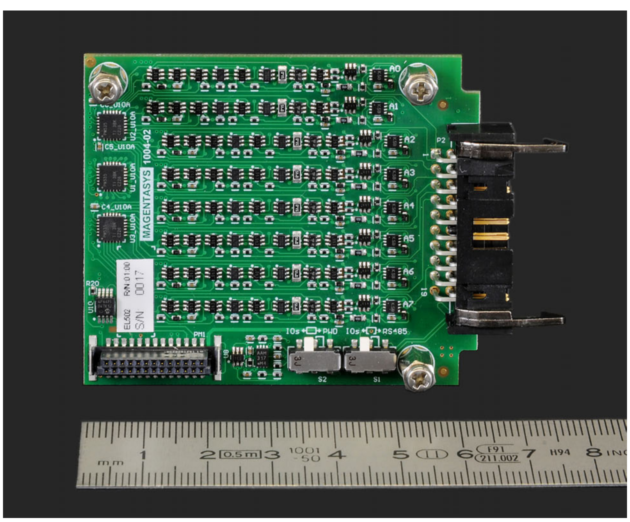

Figure 4: Close-up of the mezzanine board.

- Deported I/O: Optional external baseboard to avoid long IFC cables. It is connected to a special mezzanine on the RTM via separate Cat 5 patch cables for data and power which can be up to 350m long. For data transmission, the I^2C protocol over RS485 is used.

The IFCs are directly attached to the mezzanine boards on the RTM module. The SVEC board hosts an Spartan 6 FPGA which is able to route any signal from the mezzanines to the front connectors of the FMCs. From the FMC, the signal is plugged into a scaler module for pulse counting. Moreover, the mezzanine boards provide power to the IFC electronic. The flexibility of the system is very useful for debugging purposes: The signal of an IFC can be sent to the control system through one FMC output and can be observed using an oscilloscope or an expert system on a second output in parallel.

The front FMC connectors have even more capabilities: They can provide signals with different frequencies and can be logically combined with any input of the FMC modules.

Besides the functionality to control an IFC, the V-DIO hardware can provide and acquire arbitrary I/O signals. Each mezzanine board has 16 I/O lines which can be individually configured as in- or output at TTL or NIM level or as an open-collector output.

The whole V-DIO setup is controlled via FESA. The signal routing from the mezzanines to the FMC front connectors is freely configurable using the FESA instance file. This is an XML-based, editable file to configure the FESA class at startup. To make FESA development for the VDIO system easily adaptable, all hardware-specific functionality has been separated into an external C++ library. This way the IFC and 'arbitrary I/O' modes of the V-DIO system can be implemented quite easily in any application.

CONCLUSION AND OUTLOOK

During the 2015 beamtime, only the low energy beamlines of GSI have been in operation. Therefore, all HV dependent detectors in the synchrotron and the HEBT lines have been upgraded to the new HV system without machine interrup-

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tion. The new system is currently under extensive testing and will be put in operation with the next beamtime starting in March 2016. LASSIE is already running since 2011 and replacing the old ABLASS system successively. The IFC hardware will be upgraded to the new V-DIO system after the 2016 beamtime, since White Rabbit Timing is not yet available at the existing SIS18 synchrotron.

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